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FACE DETECTION COMPUTER PROGRAM PRODUCT FOR REDEYE
CORRECTION

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FACE DETECTION COMPUTER PROGRAM PRODUCT FOR REDEYE CORRECTION

FIELD OF THE INVENTION

5 The invention relates generally to the field of digital image processing, and in particular to a method for detecting faces and correcting redeye artifacts in digital images.

BACKGROUND OF THE INVENTION

10 When flash illumination is used for the capture of an image, sometimes the pupils of people in the image appear red. This is caused by light from the flash unit entering the pupil, reflecting off the retina, and finally exiting back through the pupil. Because light is partially absorbed by light in the retina, the pupil appears red in the image. This phenomenon is referred to as "redeye." 15 The probability of redeye being observed increases as the distance between the flash unit and the optical axis of the lens decreases. Therefore, redeye is commonly observed in images captured by a small camera with an integral flash unit.

20 US patent 6,252,976 issued June 26, 2001 to Schildkraut et al. discloses a method for automatically correcting eye color defects in an image. One shortcoming of the method is that it requires that all skin colored regions having characteristics of a human face need to be examined for the possible presence of eyes. This imposes a computational burden and increases the time required to optimally render and reproduce copies of captured images. Therefore, 25 a need exists for faster and better classification of faces in an image.

SUMMARY OF THE INVENTION

30 The need is met according to the present invention by providing a method of calculating the size of a human face in a digital image, that includes the steps of: providing image capture metadata associated with a digital image that

includes the image of a human face, the metadata including subject distance, focal length, focal plane resolution; providing a standard face dimension; and calculating the size of a human face at the focal plane using the metadata and the standard face size.

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ADVANTAGES

The present invention has the advantage that skin colored regions that fall outside the calculated range are not taken into consideration for further analysis in the redeye detection and correction portion of the algorithm, thereby increasing the speed and efficiency of the method.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing an image processing system useful in practicing the present invention;

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Fig. 2 is a detailed flowchart of the face size calculation method of the present invention; and

Fig. 3 is a graph useful in explaining the assigning of a score to the face width.

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DETAILED DESCRIPTION OF THE INVENTION

The present invention will be described as implemented in a programmed digital computer. It will be understood that a person of ordinary skill in the art of digital image processing and software programming will be able to program a computer to practice the invention from the description given below.

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The present invention may be embodied in a computer program product having a computer readable storage medium such as a magnetic or optical storage medium bearing machine readable computer code. Alternatively, it will be understood that the present invention may be implemented in hardware or firmware.

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Referring first to Fig. 1, a digital image processing system useful for practicing the present invention is shown. The system generally designated

10, includes a digital image processing computer 12 connected to a network 14. The digital image processing computer 12 can be, for example, a Sun Sparcstation, and the network 14 can be, for example, a local area network with sufficient capacity to handle large digital images. The system includes an image 5 capture device 15, such as a high resolution digital camera, or a conventional film camera and a film digitizer, for supplying digital images to network 14. A digital image store 16, such as a magnetic or optical multi-disk memory, connected to network 14 is provided for storing the digital images to be processed by computer 12 according to the present invention. The system 10 also includes one or more 10 display devices, such as a high resolution color monitor 18, or hard copy output printer 20 such as a thermal or inkjet printer. An operator input, such as a keyboard and track ball 21, may be provided on the system.

The goal of the present invention is to reduce the processing time required to detect faces in an image. The present invention makes use of metadata 15 associated with the image file or capture source. By using metadata, it is possible to calculate the expected size of a given object in the image. Specifically, it is possible to calculate the expected range of face sizes in an image. The present invention requires image capture metadata associated with a digital image. The image capture metadata includes information specific to the capture source and 20 the digital file. These metadata items may be collected by the electronics in the image capture device such as a digital still camera and/or by manual photographer input. In addition, association of the metadata to the image file can occur through the use of look-up-tables or through the use of image file formats that make provisions for recording capture information. An example of such format is the 25 Exif image file format as described in the JEIDA specification: Digital Still Camera Image File Format Standard (Exchangeable image file format for Digital Still Cameras: Exif), Version 2.1, June 12, 1998, Japan Electronic Industry Development Association.

In the following description, the present invention will be 30 described in the preferred embodiment as a software program. This program may

be implemented as part of a digital photofinishing environment or as part of a digital camera.

The metadata used in one embodiment of the present invention include:

- 5 $\Rightarrow f$ - focal length of the lens
- $\Rightarrow F_{number}$ - f-number of the lens
- $\Rightarrow R$ - focal plane resolution (pixels per inch)
- $\Rightarrow s$ - subject distance (distance from focused plane to the lens).

The following parameters can be calculated using the metadata 10 items listed above:

- $\Rightarrow d$ - lens aperture
- $\Rightarrow c$ - diameter of the circle of confusion
- $\Rightarrow l_{FAR}$ - far depth limit distance in object space measured from the lens
- 15 $\Rightarrow l_{NEAR}$ - near depth limit distance in object space measured from the lens
- $\Rightarrow M$ - Magnification factor
- $\Rightarrow W_0$ - Expected width of a face
- $\Rightarrow S(W)$ - Scoring function

20 The approach taken in the present invention is to use the subject distance metadata along with lens focal length, F -number, and image plane resolution metadata in order to determine expected face size in the image at the subject distance and at the near and far boundaries of the depth of field. Image content with the color and shape of a human face is scored based on the degree 25 that its size makes the size of an average face at the subject distance. This score, which has a maximum value of one, falls to zero for face sizes at the near and far boundaries of the depth of field. In this way, many face like-regions are bypassed for most of the image processing that is involved in redeye detection. Hence, the average processing time per image is decreased along with the false positive rate.

The application of metadata for redeye detection is divided into three stages. The first stage is the calculation of depth of field using camera metadata. The next stage is the determination of average face size at the depth of field limits and subject distance. The final stage is the integration of metadata-based expected face sizes into the existing redeye detection algorithm. Referring to Fig. 2, the face detection method of the present invention proceeds as follows. 5 First, input image data and capture condition metadata are input 22 to the process.

Next, the depth of field is calculated 24. The equations for the depth of field for a fixed circle of confusion in the image plane were taken from 10 Optics in Photography, by R. Kingslake, SPIE Optical Engineering Press (1992), pp. 92-96.

The distance between the lens and the far and near depth of field limits are:

$$l_{FAR} = \frac{s}{1 - X} \quad (1)$$

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$$l_{NEAR} = \frac{s}{1 + X} \quad (2)$$

where

$$X = \frac{c}{f \cdot d} (s - f) \quad (3)$$

In the above equations, s is the subject distance, f is the focal 20 length of the lens, d is the lens aperture, and c is the diameter of the circle of confusion. The lens aperture is simply given by the ratio between the focal length and the F -number,

$$d = \frac{f}{F_{number}} \quad (4)$$

The metadata includes s , f , and the F -number. The circle of 25 confusion, c , must be set based on a criteria for scene content to be in focus at the

image plane. Instead of setting c directly, it is calculated as a fraction r of the aperture diameter using:

$$c = r \cdot d \quad (5)$$

At a subject distance s , at which X equals one, the far depth field limit l_{FAR} goes to infinity. This subject distance is called the hyperfocal distance. For the purpose of calculation, when X is equal to or greater than 1.0, the value of l_{FAR} is set to the very large distance 10^7 meters.

Next, the expected face size expressed as a width in pixels is calculated 26. The expected width in pixels of a face at a distance l from the camera is given by the equation,

$$W_0 = D_{face} \cdot M \cdot R, \quad (6)$$

where D_{face} is the average width of a human face, M is the magnification, and R is the image plane resolution in pixels/unit length. The magnification is given by,

$$M = \frac{f}{l - f}. \quad (7)$$

15 The average face size, D_{face} , is set to 6.0 inches (0.15 meters).

Next, a scoring function, $S(W)$, that is used to assign a metadata based score to a candidate face is calculated 28 shown by the graph 30 in Fig. 3, which relates the score to the face width W expressed in pixels. As shown in the figure, the scoring function peaks at a value of 1.0 at the expected face width W_0 . 20 It goes linearly to zero at the minimum face width W_{min} and a maximum face width W_{max} that correspond to distances from the camera of l_{Far} and l_{Near} , respectively.

The equation for the scoring function is as follows:

$$\begin{aligned} & \text{if } (W_{min} < W < W_0) \quad S(W) = 1 - \frac{W_0 - W}{W_0 - W_{min}} \\ & \text{else if } (W_0 < W < W_{max}) \quad S(W) = 1 - \frac{W - W_0}{W_{max} - W_0} \\ & \text{else} \quad S(W) = 0 \end{aligned} \quad (8)$$

The redeye correction algorithm described in US Patent 6,252,976, which is incorporated herein by reference, performs image processing and classification in order to locate candidate face regions in an image. According to the present invention, metadata is used in the redeye algorithm to assign a score 5 using Eq. (8) to each candidate face.

Finally, a test is made 31 to determine if a candidate face region is a face. A face candidate is classified as a face 32 if

$$S(W_i) \geq S_{min} \quad (9)$$

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where S_{min} is a parameter that sets the minimum face metadata score. The face candidate that is classified as a face is then evaluated for the presence of redeye using the redeye correction algorithm disclosed in US Patent 6,252,976. A face candidate region having a score that is below the threshold is not evaluated 34 15 during the redeye detection phase of the redeye correction algorithm.

The red-eye detection and correction algorithm disclosed in the preferred embodiment(s) of the present invention may be employed in a variety of user contexts and environments. Exemplary contexts and environments include, without limitation, wholesale digital photofinishing (which involves exemplary 20 process steps or stages such as film in, digital processing, prints out), retail digital photofinishing (film in, digital processing, prints out), home printing (home scanned film or digital images, digital processing, prints out), desktop software (software that applies algorithms to digital prints to make them better -or even just to change them), digital fulfillment (digital images in - from media or over the 25 web, digital processing, with images out - in digital form on media, digital form over the web, or printed on hard-copy prints), kiosks (digital or scanned input, digital processing, digital or hard copy output), mobile devices (e.g., PDA or cellphone that can be used as a processing unit, a display unit, or a unit to give processing instructions), and as a service offered via the World Wide Web.

In each case, the algorithm may stand alone or may be a component of a larger system solution. Furthermore, the interfaces with the algorithm, e.g., the scanning or input, the digital processing, the display to a user (if needed), the input of user requests or processing instructions (if needed), the output, can each be on the same or different devices and physical locations, and communication between the devices and locations can be via public or private network connections, or media based communication. Where consistent with the foregoing disclosure of the present invention, the algorithm(s) themselves can be fully automatic, may have user input (be fully or partially manual), may have user or operator review to accept/reject the result, or may be assisted by metadata (metadata that may be user supplied, supplied by a measuring device (e.g. in a camera), or determined by an algorithm). Moreover, the algorithm(s) may interface with a variety of workflow user interface schemes.

15 The algorithm(s) disclosed herein in accordance with the invention may have interior components that utilize various data detection and reduction techniques (e.g., face detection, eye detection, skin detection, flash detection).

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be affected within the spirit and scope of the invention.

PARTS LIST

- 10 image processing system
- 12 image processing computer
- 14 network
- 15 image capture device
- 16 digital image store
- 18 monitor
- 20 printer
- 21 operator input device
- 22 image data and metadata input step
- 24 calculate depth of field step
- 26 calculate candidate face width step
- 28 calculate score step
- 30 graph
- 31 test for face step
- 32 classify as face and evaluate for redeye step
- 34 do not evaluate for redeye step